Salton Sea Financial Assistance Program
Project Support Application: Work Plan for Selenium Bioaccumulation and Ecological Risk Assessment at Four Wetlands Near the Salton Sea

Prepared for the Salton Sea Financial Assistance Program

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INTRODUCTION

Treatment wetlands have been shown to effectively remove many constituents of concern in the Salton Sea watershed, notably nutrients, sediments, and pathogens. For example, at the Brawley and Imperial wetlands, where the performance was assessed after 5 years of operation, it was found that the removal for sediments was >90 percent, for nitrogen, 60-80%, and for phosphorus, 60-70% (Tetra Tech, 2006; Johnson et al., 2009; Kadlec et al., 2010). When a network of wetlands (totaling more than 1,000 acres) is modeled over the length of the New and Alamo Rivers, there are major load reductions of nitrogen, phosphorus, and suspended sediments to the Salton Sea (Tetra Tech, 2007). However, the widespread acceptance of treatment wetlands is limited by concerns regarding selenium accumulation in the ecosystem and associated effects on birds and other wildlife. This Work Plan describes activities to be undertaken for improved characterization of selenium behavior in three existing wetlands and potentially one new wetland. The proposed research includes compilation and analysis of previously collected data, new biological surveys and data collection on water quality, sediments, and in plant and animal tissues in the wetlands and surrounding habitats. The data will allow assessment of the performance of the wetlands from a water quality and ecological standpoint, and will be used to conduct a formal ecological risk assessment to support decision-making on the future use of these wetlands for water quality improvement. The evaluation of existing water quality data, new data collection in biota, and the ecological risk assessment for wetlands operating under relatively steady state conditions for over a decade will fill important data gaps relating to a key restoration and treatment alternative for the Salton Sea.

Potential pathways of selenium uptake and transfer through the food web in shallow freshwater aquatic habitats, such as the proposed wetlands, are shown in Figure 1. Selenium in water bioconcentrates to higher levels through the food-web, with the highest concentrations and adverse impacts occurring in the top species. Receptor species to be considered in this work will include plants, benthic and aquatic invertebrates, amphibians, fish, and wetland-associated birds and mammals.

The two New River wetland sites for this study have been continually operated for 12 years with inflow selenium concentrations at times exceeding 10 micrograms/liter offer unique opportunities to evaluate potential wildlife risks that might occur if more wetlands in the Salton Sea watershed were used for habitat restoration or water treatment. The recently constructed Shank Road wetland and proposed Holtville wetland on the Alamo River are similarly suitable study sites, for a total of four sites. This study will expand on the selenium investigation and ecological risk assessment previously conducted at the Brawley and Imperial pilot wetlands on the New River (Tetra Tech, 2007) and will consist of the following elements:

1) Evaluation of water quality and inflow data on nutrients, suspended sediments, and pathogens collected in the New River wetlands and surrounding regions from 2001 to 2012, computing mass balances, infiltration and pollutant removal rates. A portion of these data (up to 2005) have been analyzed in previous work. This effort will build on the past work and evaluate process changes over the 12-year period of operation.
2) Evaluation of selenium mass balances over 2001-2012 at the New River wetlands, and new data from the Alamo River wetlands.
3) Collection of tissue samples from all four wetlands, and characterization of selenium concentrations in them.
4) Development of a formal ecological risk assessment for the wetlands, including exposure assessment, toxicity assessment, and risk characterization.

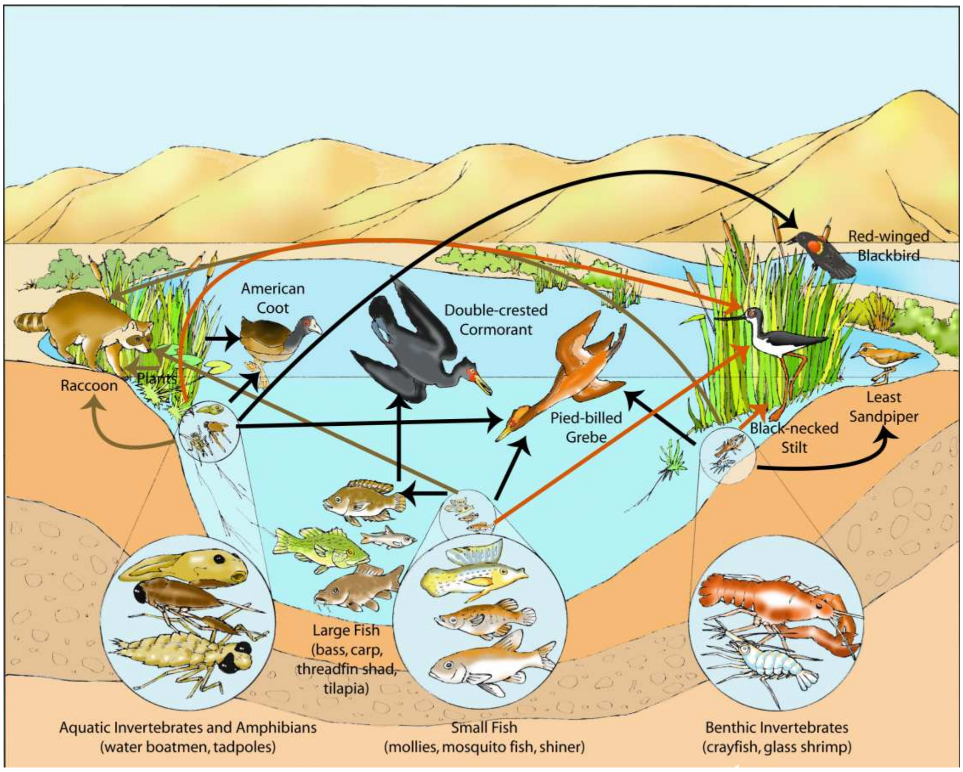


Figure 1. Example food web for risk assessment in a shallow freshwater habitat in the Salton Sea region (source: Tetra Tech, 2007: New and Alamo River Wetlands Master Plan).

RESEARCH OBJCTIVES

The Salton Sea Authority (the Authority) proposes to conduct a research study on selenium bioaccumulation and potential ecological effects in constructed treatment wetlands along the New and Alamo Rivers south of the Salton Sea. Four wetlands are proposed to be studied for this purpose: existing wetlands at Brawley and Imperial on the New River, and at Shank Road on the Alamo River. Funding is being sought, through a separate application, for the construction of a wetland at Holtville, and should this grant be successful, selenium bioaccumulation at the Holtville wetland will also be studied. The wetland locations are shown on Figure 2.

The goals of the project are to:

(A) Characterize selenium concentrations in sediment and surface water and determine the extent and distribution of selenium transfer into the food webs at the four treatment wetlands.

(B) Develop site-specific or predicted selenium concentrations in tissues of plants and animals comprising key food sources for the species of concern in the wetlands.
(C) Determine the potential for adverse effects on species of concern in the four wetlands.

The associated objectives of the project are to:

(A) Measure the magnitudes of selenium concentrations in sediment, surface water, and dominant plants, invertebrates, and fish resulting from bioaccumulation (i.e., uptake and trophic transfer).
(B) Calculate representative site-specific media and tissue concentrations and develop bioaccumulation models of potential relationships between selenium concentrations in sediment or surface water and those in multiple types of co-located plants, invertebrates, and fish from site-specific data.
(C) Calculate a selenium mass balance for each wetland depicting the partitioning of selenium among distinct abiotic and biotic wetland compartments.
(D) Conduct ecological risk assessments to evaluate potential effects of selenium on species of ecological and regulatory concern in each wetland.

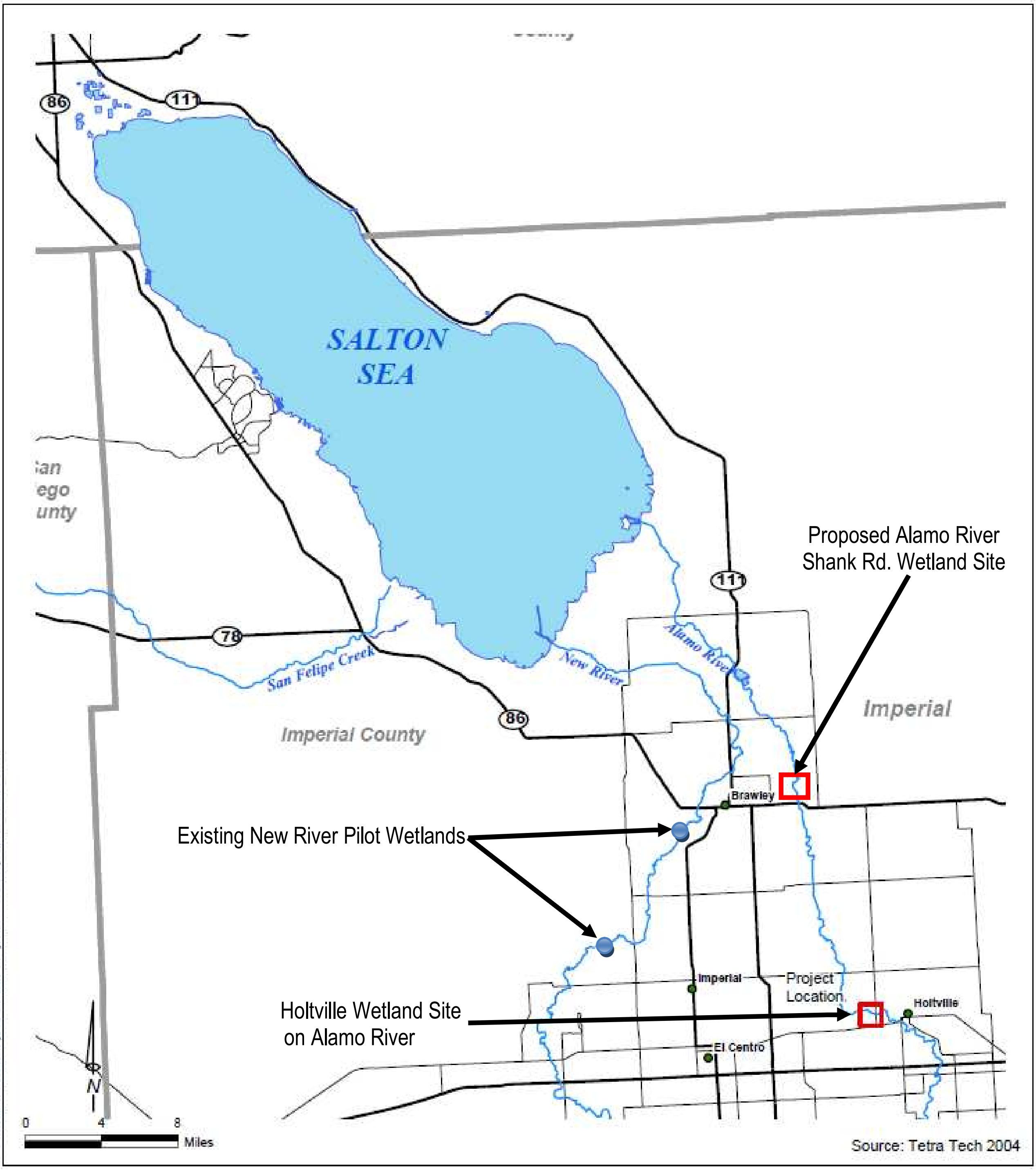


Figure 2: Project Location Map

MAJOR TASKS AND DELIVERABLES

The proposed research will include compilation of existing data, evaluation of mass balances of key pollutants, collection of new water quality and tissue data, and the development of an ecological risk assessment for the wetlands. A key hypothesis of the proposed work is that the full evaluation of the performance and selenium risk across multiple operational wetlands—as described below—will provide a basis for future decision-making relating to their greater use in the Imperial Valley.

Task 1 of the study will be to review and evaluate both (1) previous selenium data from surface water, sediment, and tissue samples from the Brawley and Imperial pilot wetlands that were evaluated in the initial investigation (Tetra Tech, 2007) and (2) subsequent surface water and sediment monitoring data collected regularly at these two wetlands.

Task 2 will involve collection of field data at four wetland sites. A field sampling plan will be prepared to guide the collection of samples at each wetland. A reconnaissance-level biological inventory of plants and animals present at the wetlands may be conducted to help identify species of concern for the risk assessment and to focus the tissue sampling effort. The Salton Sea Species Conservation Habitat Project, the Salton Sea Ecosystem Monitoring and Assessment Plan defines ecological restoration and enhancement objectives aimed at improving the overall ecological support functions provided in the Salton Sea watershed. The constructed wetlands offer the opportunity to contribute toward meeting these programmatic objectives. This grant request includes an element to examine avian use ecological support functions of these constructed wetlands. Focal species depending on the specific designs of the constructed wetlands (eg, ratio and configuration of emergent vegetation to open water and total size of wetland) include (see Table 3.4-4 of the Salton Sea Species Conservation Habitat Project EIS/R):

- Redhead – nesting, if constructed wetlands mix emergent freshwater marsh and adjacent open water)
- White tailed kite – forage of small rodents
- American peregrine falcon – forage of wetland birds
- Least bittern – forage of invertebrates
- Lesser sandhill crane – forage of invertebrates
- California black rail – nesting and forage
- Yuma clapper rail – nesting and forage
- Gull-billed tern – forage
- Burrowing owl – nesting on wetland edge

- Yellow headed blackbird – nesting and forage

Assessment approaches would include appropriately timed field surveys of nesting and foraging use of these constructed wetlands, using point and/or line transect survey methods based upon access considerations at each constructed wetland. Surveys would include documenting the vegetation types and percent cover including of open water associated with the forage and nesting observations.

Field sampling and laboratory analyses will be conducted to measure concentrations of selenium in sediment, surface water, and tissues of biota (plants, invertebrates, and fish) of relevance to higher trophic level species including birds (particularly shorebirds, seabirds, waterfowl), wetland-associated mammals, and predatory fish. Measured selenium concentrations in these plant and prey tissues will be applied in the Exposure Assessments of the ecological risk assessments, as described below. This investigation will focus on the overall bioaccumulation patterns in the wetland system at each site that result from complex and interrelated variables that cumulatively contribute to bioaccumulation relationships. These variables include relative concentrations of differentially available selenite and selenate in the wetland system, biologically generated selenomethionine, hydrology and transport, sediment and water properties affecting bioavailability, competitive uptake with chemicals including sulfate and elemental sulfur, and differential uptake by specific plant and animal species. Sediment, water, and tissue data will be collected over two seasonal sampling events, if feasible, and will be used to evaluate the extent of selenium uptake from abiotic media and trophic transfer to organisms in distinct ecological and taxonomic groups present at each wetland. The biota to be sampled for tissue concentrations will be selected based on the dominant species composition at each site and relevant exposure pathways (i.e., prey species) for species of concern including shorebirds, seabirds, and waterfowl. Preliminary target sample sizes were estimated based on the reasonable minimum numbers of samples required for site-specific statistics and regressions, tissue biomass observed to be available during the 2007 sampling at Brawley and Imperial wetlands, and overall cost. The numbers of samples to be collected at each site are 8-10 sediment samples, 8-10 surface water samples, 5-10 aquatic plant and algae samples, 5-10 samples per benthic invertebrate group (i.e., macroinvertebrates and smaller invertebrates), 5-10 samples per aquatic invertebrate group, 5-10 amphibian/tadpole samples, and 10-20 samples per fish group (e.g., small, medium, and large fish). To achieve adequate sample sizes for selenium analyses, sample composites of some tissue groups may be necessary.

Task 3 will involve the water quality modeling of all monitored contaminants, to estimate influent loads, effluent loads, infiltration and other losses, following the approach previously used in Tetra Tech (2006), Johnson et al. (2009), and

Kadlec et al. (2009). This will allow assessment of pollutant removal efficiency in each wetland over time.

Task 4 will develop a model and estimated rates of uptake of selenium through the food web for each wetland studied. This is of particular importance in the two older wetlands that have received more than a decade of elevated selenium loadings in their inflows. At some wetlands, tissue sample sizes for certain taxonomic and functional groups may be insufficient to adequately characterize potential exposures of higher trophic level species in the risk assessments. To supplement site-specific data as needed, predictive bioaccumulation models will be developed using surface water, sediment, and tissue samples collectively sampled from all four wetlands. These empirical statistical models are anticipated to be simple linear regressions for sediment-to-tissue and surface water-to-tissue concentrations, with data transformed as appropriate to satisfy statistical assumptions. Separate regression models will be developed for each set of media and tissues (e.g., sediment-to-plant, sediment-to benthic invertebrate, water-to-aquatic invertebrate, and water-to-fish). If determined to be important for assessing exposures to bird species of concern, distinct regressions may also be developed for sub-types of biota (e.g., smaller benthic invertebrates versus benthic macroinvertebrates, or lower versus higher trophic level fish), if feasible. The bioaccumulation models will be applied in the Exposure Assessment of the ecological risk assessments (see below).

Task 5 is the performance of an ecological risk assessment to evaluate the potential for adverse impacts of selenium on species of concern (i.e., ecological receptors), including plants, aquatic organisms, birds, and other animals at the two existing pilot wetlands on the New River, Shank Road wetland on the Alamo River, and proposed Holtville wetland on the Alamo River. The ecological risk assessments will be conducted in a four-step process:

(A) Problem Formulation
(B) Exposure Assessment
(C) Toxicity assessment
(D) Risk characterization

The scope and general methodology of the risk assessment will be consistent with a predictive (i.e, baseline or “Phase I”) ecological risk assessment as described in guidance by the U.S. EPA (1992, 1998) and California DTSC (DTSC 1996). These components are briefly described below.

In the Problem Formulation phase the key concepts to be evaluated in the risk assessment will be developed, including definitions of the sites and potentially affected areas, habitats and receptors of concern, and a conceptual model showing selenium transport and complete exposure pathways to biota of concern (i.e., ecological receptors). The risk assessment will focus in particular on risks to birds of highest concern for regional population impacts and selenium effects (i.e., shorebirds, seabirds, and waterfowl) including the California brown pelican, American white pelican, eared grebe, western sandpiper, gull-billed tern, black skimmer, American avocet, and black-necked stilt.

The Exposure Assessment will select representative species for each taxonomic and trophic group, determine representative exposure point concentrations, apply exposure equations, identify exposure parameters for each representative species, and calculate dietary exposures. To identify potential risks from selenium, dietary exposures will incorporate selenium concentrations in water, sediment, algae, plants, benthic and aquatic invertebrates, and fish. Measured, site-specific selenium concentrations will be supplemented as needed with predicted concentrations from the bioaccumulation models developed from the combined data set from the four sites, including both previously collected and new data. Data collection and modeling will be prioritized to maximize the accuracy of risk estimates for the above bird species of concern.

In the Toxicity Assessment, a focused review of toxicity data on selenium will be conducted to develop toxicity reference values (TRVs) for each receptor group (plants, invertebrates, fish, amphibians, birds, and mammals). The TRVs applied in the prior risk assessment will be selectively modified as appropriate using recent toxicity data in the primary literature and secondary sources. In birds, elevated exposures to selenium are associated with adverse reproductive and developmental effects including reduced growth and survival of offspring (Ohlendorf, 1989). Therefore, these TRVs will be protective of potential population-level impacts associated with reproductive and developmental effects. Selenomethionine is generated and bioconcentrated by algae and aquatic invertebrates. However, total selenium, selenite, or selenate will likely be favored as the most appropriate basis for TRVs. The quality and relevance of study methodology applied, mineral forms of selenium tested (selenite and selenate), and relationships between no observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs) will be considered in developing TRVs from the literature and secondary sources (e.g., U.S. EPA, 2007; Sample et al., 1996; Wilson et al., 2002; Adams et al., 2003). Appropriate TRVs will be higher than the nutritional requirements. In addition to oral TRVs for birds, selenium concentrations in bird eggs collected at the project sites by the U.S. Fish and Wildlife Service may analyzed to provide additional exposure and risk estimates based on egg concentrations associated with critical effects on birds.

The Risk Characterization will integrate the products of the Exposure Assessment and Toxicity Assessment to calculate estimates of potential risk (i.e., hazard), as indicated by the hazard quotient (HQ; i.e., an index of the predicted exposure divided by the toxicity threshold). Since some TRVs may be lower than regional background or ambient concentrations, site-specific HQs may be compared to HQs for exposures at appropriate reference areas (e.g., agricultural drains in the Imperial Valley, New and Alamo Rivers, and/or the Salton Sea) to estimate incremental hazards over ambient conditions. Multiple lines of evidence will be used to determine the potential for risks, including magnitudes of HQs, frequency of detection in samples, size and habitat quality of affected areas, presence of special status species, confidence in exposure factors and toxicity data, and consideration of LOAEL-based HQs. Key uncertainties in data, parameters, and assumptions and the consequences of these uncertainties for the risk estimates will be discussed. These uncertainties may include ambient exposures, spatial relationships between the sizes of species' foraging areas and wetlands, bioaccumulation and toxicity of selenium, and potential for population-level impacts.

To verify any significant risks predicted for lower trophic level organisms, focused bioassays (i.e., laboratory toxicity studies on site-specific water or sediment samples) will be considered. These may include plant, invertebrate, or amphibian bioassays. Bioassay results for selected sites would be compared with bioassay results from the most appropriate available reference sites. Bioassay data would be statistically analyzed for differences in effects on organisms between samples from project and reference sites, and also would be statistically analyzed to identify effects that are potentially correlated with selenium concentrations.

Key products of this research will include compiled databases of water quality and tissue concentrations, quantification of long-term wetland performance efficiency, and the risk assessment for the New and Alamo River wetlands, each treated as a group.

PROJECT TEAM QUALIFICATIONS

Key participants in the project will include:

William Brownlie, PhD, PE, Program Manager

Dr. Brownlie is an expert on water resource planning and hydraulic and hydrodynamic studies, for which he was awarded the Alfred Noble Prize, presented by the combined engineering societies of the United States, for his paper entitled "Prediction of Flow Depth and Sediment Discharge in Open Channels," and brings his experience managing the Salton Sea restoration project.

Dr. Brownlie has more than 30 years of experience in water resource planning and analysis projects and engineering and program management for water resource projects. He has been working on projects related to Salton Sea restoration for the past 12 years for the Authority and the Bureau of Reclamation. He was also Program Manager for the New and Alamo River Wetlands Master Plan Project that was funded by the State Wildlife Conservation Board. Dr. Brownlie has familiarity with the issues and stakeholders through his regular attendance and participation in public meetings throughout the region related to the Salton Sea including Salton Sea Authority Board meetings. He will bring that knowledge and experience to this project. He has recently been overseeing the Salton Sea shallow habitat demonstration project to demonstrate the feasibility of developing shallow saline habitat near the Salton Sea, next to the Alamo River. Through more than 75 different projects related to Salton Sea restoration, Dr. Brownlie has demonstrated his ability to manage multidisciplinary teams and to complete projects on schedule and within budget.

Sujoy Roy, PhD, Project Manager

Specializing in hydrology, groundwater, water resources, and water quality modeling, Dr. Roy has extensive experience in designing and preparing focused research projects in southern California, including multiple directly relevant projects at the Salton Sea. He currently manages the operation and maintenance of a 100-acre shallow habitat pilot project at the Sea.

Dr. Roy has more than 15 years of experience in focused research on water quality restoration projects, including major projects related to restoration of the Salton Sea and the Everglades in Florida. For the past eight years, he has worked with Dr. Brownlie extensively on water quality projects at the Salton Sea. Dr. Roy was the Project Manager of the master plan for treatment wetlands along the New and Alamo rivers and evaluated treatment removal efficiency and potential risk due to bioaccumulative substances. He managed an integrated study of Salton Sea water quality, including field monitoring, modeling, and pilot testing of ozonation to remove hydrogen sulfide. He was recently the Program Manager for demonstration shallow habitat near Niland, for which Tetra Tech was responsible for operation and maintenance over a six-year period.

Philip Bachand, PhD, Principal Engineer

Specializing in water quality and water resources management as related to wetlands, agricultural and other semi-natural systems. Dr. Bachand developed management practices and design recommendations for improving nitrate removal by the Prado Basin wetlands from the Santa Ana River, which has enhance recharge to and water quality in their groundwater basin

Dr. Bachand has been involved in applied experimental research on water resources issues relating to agriculture, wetlands, stormwater and other similar environments since 1992. He focuses on developing designs and management practices to reduce nonpoint water quality impacts and to enhance water resources as related to these systems. He is currently a principal investigator on a number of multi-disciplinary, multi-organizational projects addressing key water resources issues in California: the local, regional and statewide impacts of growing rice in the Delta as related to drinking water quality, water conveyance, greenhouse gas emissions and carbon sequestration; implementing on-farm flood flow capture management practices along the Kings River to reduce flood risks and offset chronic regional groundwater overdraft; developing management practices for managed wetlands in Suisun Bay to reduce low DO events and MeHg export; managing dairy lagoon water to improve nutrient use efficiencies and reduce groundwater impacts; implementing coagulant dosing in combination with wetlands to remove nutrients, DOC and disinfection byproducts from stormwater and agricultural drains; characterizing and developing management practices to reduce MeHg export from agricultural and natural wetlands in the Yolo Bypass. Working closely with scientists, engineers and economists, Dr.

Bachand approaches environmental challenges from the perspective of developing sustainable, defensible and scientifically-based solutions.

Kevin Torres, M.S., Senior Scientist

Specializing in ecotoxicology, ecological risk assessment, ecology, and wildlife biology, Mr. Torres has extensive experience in conducting risk assessments and bioaccumulation studies for wetland, aquatic, and terrestrial sites in California. He also conducted the selenium and pesticide ecological risk assessment for the Brawley and Imperial pilot treatment wetlands on the New River.

Mr. Torres has more than 15 years of experience in the fields of ecological risk assessment, ecotoxicology, ecology, and wildlife biology. He has a M.S. degree in Ecology with an emphasis on ecotoxicology. Mr. Torres has conducted ecological risk assessments in support of site assessments and remedial investigations for numerous wetland, aquatic, and terrestrial sites in California. In support of risk assessments, he has designed sampling investigations for chemical concentrations in plant and animal tissues, water, sediment, and soils. Mr. Torres has conducted uptake and bioaccumulation studies on metals, PCBs, and perchlorate in plants, invertebrates, and small mammals in wetlands, aquatic habitats, and terrestrial habitats in California. Mr. Torres has contributed to all aspects of ecological risk assessments, including site characterizations, chemical data management, exposure and bioaccumulation modeling, toxicity assessment, and risk characterization. He has extensive experience in reviewing toxicity research, analyzing bioassay data, and ecologically relevant toxicity reference values for application in risk assessments. He has also developed and applied risk-based cleanup goals in support of remedial decision making.

Stephen Charlton, Senior Program Manager, Imperial Irrigation District

Specializing in water quality, total maximum daily load (TMDL) evaluations, and wetland restoration and monitoring. Mr. Charlton has extensive recent experience in restoration design and monitoring at the Brawley, Imperial, Shank Road, and Holtville pilot and treatment wetlands.

Mr. Charlton obtained his Bachelor of Science degree in Civil Engineering from San Diego State University in 1997. He has been employed by the Imperial Irrigation District (IID) since 1997 and is a Senior Program Manager, supervising the Water Department's Water Quality, TMDL, and Vegetation Management Unit. Mr. Charlton manages IID projects that pertain to water quality issues, including TMDLs, wetlands, Title 22, and NPDES discharge permits in coordination with regulatory and other agencies. Mr. Charlton is a member of the Citizen's Congressional Task Force on the New River, participating in a leading role which has included planning, design, and construction oversight of the Brawley and Imperial Pilot Wetland sites and is currently advising on the Shank Road and Holtville treatment wetlands. He has planned, managed, and implemented the monitoring and sampling programs at the two established pilot wetland sites since 2001.

Additional staff for the project include Stuart Siegel, Ted Donn, Gary Wortham, Karen Dikeman, and Colleena Perez, each of whom have specific experience related to field work in the Salton Sea wetlands and to ecological risk assessment. Resumes of all staff proposed for this grant application are included as an attachment. The organization chart for the team is shown in Figure 3.

SCHEDULE

The anticipated timeframe of this project will consist of approximately three years. During the first year, beginning after the grant award, previously collected selenium monitoring data will be reviewed. In addition, field samples will be collected and analyzed from the existing Brawley and Imperial pilot wetlands on the New River and at the recently constructed Shank Road wetland on the Alamo River. To the extent feasible, data analyses will be initiated in support of the selenium bioaccumulation evaluation, mass balance evaluation, and ecological risk assessments. During the second year, field samples will be collected and analyzed from the proposed Holtville wetland on the Alamo River. The selenium evaluations and ecological risk assessments will be conducted. During the third year, it is anticipated that all study tasks will be finalized. Figure 4 illustrates key elements in the schedule assuming a start date of January 1, 2013.

Figure 3
Selenium Bioaccumulation and Ecological Risk Assessment at Four Wetlands Near the Salton Sea: Project Team Organization

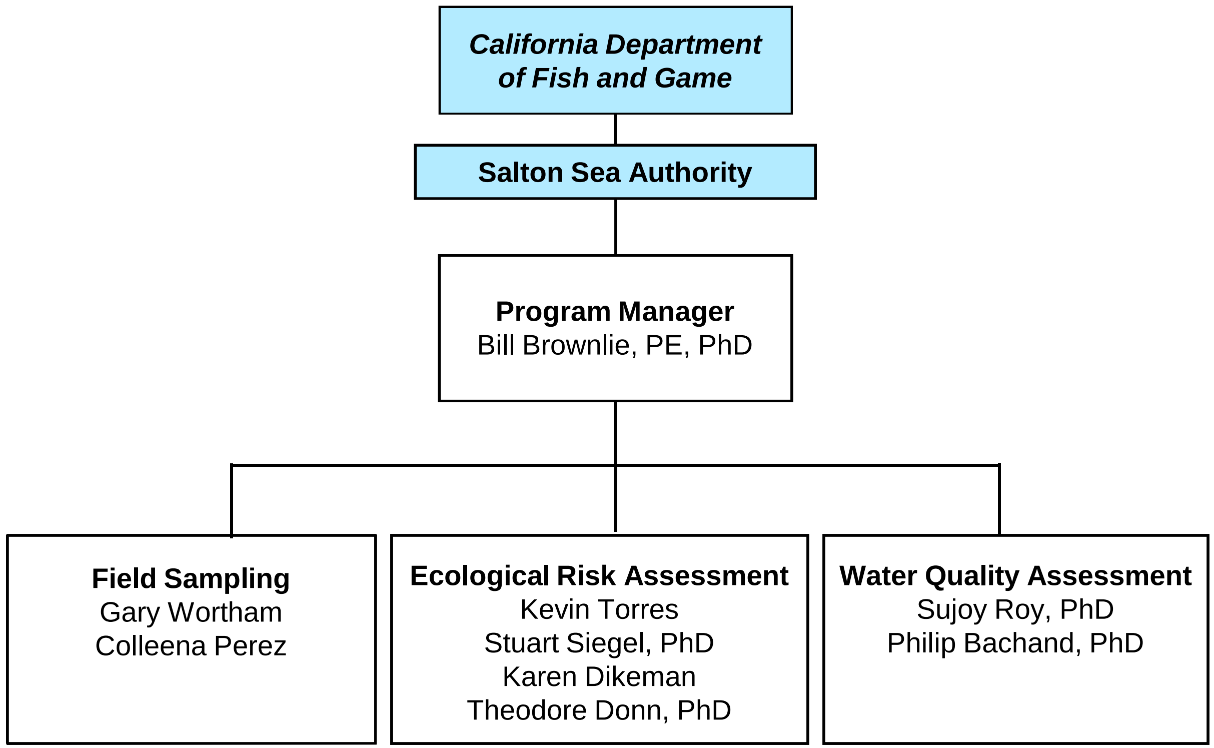
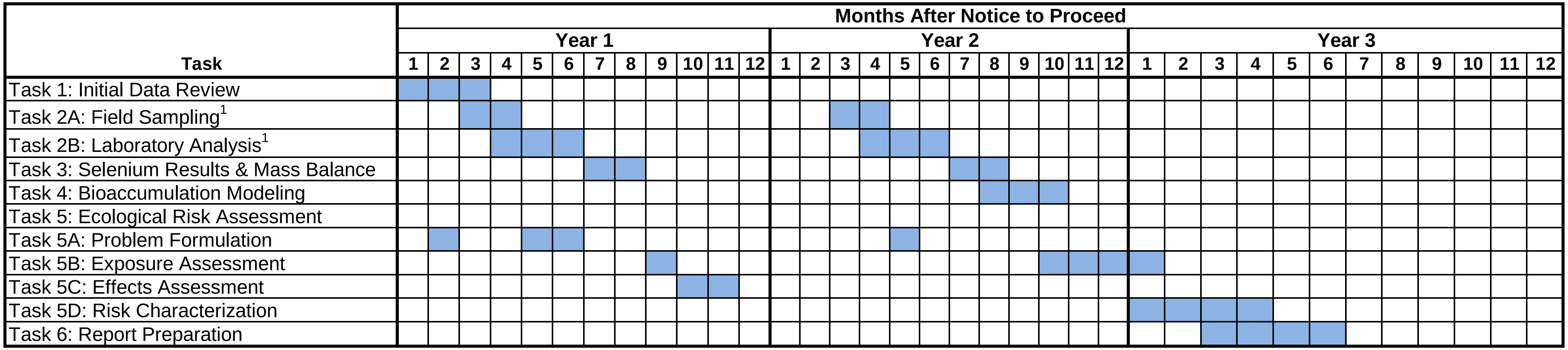


Figure 4
Project Schedule for
Selenium Bioaccumulation and Ecological Risk Assessment at Four Wetlands Near the Salton Sea



Note:

[1] Field sampling during spring 2013 is contingent on the notice to proceed occurring by January 1, 2013. Field sampling and laboratory analyses will be conducted during the first year for the Brawley, Imperial, and Shank Road wetlands, and during the second year for the proposed Hotville wetland.

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